SYSTEM AND METHOD FOR OPTIMIZED UTILIZATION OF CODE RESOURCE IN COMMUNICATION NETWORKS

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FIELD AND BACKGROUND OF THE INVENTION

The present invention relates to a system and method for
enhancing utilization of code resource in terrestrial or
10 cellular systems, preferably to terrestrial cellular CDMA
(Code Division Multiple Access) systems and methods.

The invention addresses issues related to cellular systems,
e.g. terrestrial cellular CDMA systems, where there is a need
15 for optimized utilization of code resource. This is e.g. the
case for the downlink of UMTS (Universal Mobile
Telecommunication System), where a finite set of
channelization codes are available. It is known that problems
may arise when advanced capacity enhancing features are being
20 introduced such as e.g. smart antennas (SA).

SUMMARY OF THE INVENTION

25 According to one aspect, the invention provides a method as
defined in the independent method claim.

According to a further aspect, the invention provides a
system as defined in the independent system claim.

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According to another aspect, the invention provides a network
element as defined in the independent network element claim.

The invention provides a code efficient solution for cases
35 where multiple beamforming channels, preferably PDSCHs (PDSCH

= Physical Downlink Shared Channel) are applied.

The method, system and network element in accordance with
embodiments of the invention preferably provide a code

5 trunking efficient solution. This means that code resources
are better utilized, so the BS (Base Station) can carry a
higher amount of traffic (e.g. higher number of user) with
less scrambling codes. This is a major advantage, as
introduction of additional scrambling codes typically results

10 in a capacity loss, as the orthogonality properties are
partly destroyed within the cell. The invention therefore
results in a capacity gain.

This gain is also present for HSDPA (High Speed Downlink

15 Packet Access), even though HSDPA has the option of using
higher order modulation schemes to avoid code blocking. This
is true since usage of multiple codes (equivalent to lower
spreading factor) is more spectral efficient, compared to
using higher order modulation techniques.

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BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 shows a block diagram of BS architecture in an

25 embodiment of a system in accordance with the invention when
using smart antennas with a grid of fixed downlink
beamforming,

Fig. 2 illustrates beam allocation of primary and

30 secondary scrambling code, physical channels carrying data,
and common broadcast channels, in case of cell splitting, of
an embodiment of a system and method in accordance with the
invention,

35 Fig. 3 shows an illustration of a channelization code

tree for under one scrambling code. The black nodes in the tree are reserved for PDSCHs under different beams,

Fig. 4 illustrates an example of smart parallel packet scheduling for optimized code resource allocation, in an embodiment of a system and method in accordance with the invention, and

Fig. 5 shows an example of poor un-coordinated packet scheduling.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS OF THE INVENTION

Fig. 1 shows a basic structure of a system in accordance with an embodiment of the invention. Fig. 1 illustrates a block diagram of a BS (base station) architecture when using smart antennas with a grid of fixed downlink beamforming. The system of Fig. 1 involves a network element implemented as a digital beamformer network 1 which generates N directional beams and one beam covering the complete sector. The beamformer network 1 preferably includes two or more up to M beamformers, and sends M signals to a uniform linear antenna array 2 which comprises M antenna elements. The beamformer network 1 includes a selection means for selecting spreading factors, in particular a minimum Spreading Factor for the beams.

The beamformer network 1 receives the signals of the common pilot channel and of the secondary pilots and user dedicated signals P_1 to P_N and forms there from the M antenna signals to be applied to the antenna array 2.

An estimation means 3 calculates, i.e. estimates, new power

levels for each beamformer of the beamformer network 1,
condition on admission of a new user with certain QoS
(quality of service) attributes. The estimation means 3
receives the the current average transmit power on the N

5   beams (P_1 to P_N), the average transmit power of the sector
beam as well as information on new user(s) such as required
Eb/No, bit rate, pilot measurement from the user, selected
beam. The estimation means 3 generates input to radio
resource management algorithms such as AC (admission

10   control).

The present invention also addresses issues related to
optimized utilization of code resource in cellular systems,
e.g. terrestrial cellular CDMA systems. In some cases, e.g.

15   for downlink of UMTS, only a finite set of channelization
codes is available. This causes some potential problems when
advanced capacity enhancing features are to be introduced
such as e.g. smart antennas (SA).

20   In this implementation of the invention, the example case of
introducing SA (smart antenna) at the BS in UMTS is
discussed, and a method and structure for effectively
utilizing code resources are shown. In particular the down
link shared channel (DSCH) is considered, which is

25   particularly suited for bursty high bit rate packet traffic.
Embodiments of the invention also cover the enhanced DSCH
called the high speed downlink packet access channel (HSDPA).

For the downlink (DL), a finite set of fixed directional

30   beams is assumed, where each beam carries a secondary common
pilot channel (S-CPICH). In addition, it is assumed that a
beam (sector beam) is provided which covers the complete
sector.

35   A block diagram for the DL control is pictured in Figure 1.

All channels which must be broadcast in the entire cell are
therefore transmitted on the sector beam shown by a dotted
line in Fig. 2, while dedicated channels are transmitted on

5   the directional beams (beams 1 to 8) shown in Fig. 2 by
dotted and dot-and-dash lines. This is illustrated in Figure
2, where the following channels CCPCH, CPICH, AICH, PICH, and
SCH are transmitted on the sector beam, while DPCHs are
transmitted under narrow directional beams. (CCPCH Common

10   Control Physical Channel, CPICH Common Pilot Channel, AICH
Acquisition Indication Channel, PICH Paging Indication
Channel, SCH Synchronization Channel)

Note that beamforming on PDSCH also is possible. Different

15   scrambling codes can also be allocated to each beam in order
to avoid potential channelization code shortage.

In general, it is typically found that the capacity gain from
introducing beamforming antennas is so large, that at least 2

20   to 3 scrambling codes are needed per cells in order to avoid
channelization code blocking (i.e. hard blocking).

As an example, Figure 2 shows a case where two scrambling
codes are deployed, so each scrambling code covers four

25   directional beams. The primary scrambling code is used for
the directional beams 1 to 4 shown at the left half portion
of Fig. 2, whereas the secondary scrambling code is used for
the directional beams 5 to 8 shown at the right half portion
of Fig. 2.

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Fig. 2 graphically illustrates the beam allocation of primary
and secondary scrambling code, physical channels carrying
data, and common broadcast channels, in case of cell
splitting.

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Fig. 2 also shows the base station 4 equipped with the e.g.
smart antenna array 2. Further, the base station 4 includes a
packet scheduler 5. The packet scheduler 5 can also be
arranged remote from the base station4 at an appropriate
5   position.

For cells with beamforming SA, it is assumed that one PDSCH
is being transmitted under each beam. This means that the
PDSCHs transmitted under the same scrambling code, but
10 different beams, all share the same root PDSCH channelization
with a certain minimum spreading factor (SF) denoted
$SF_{DSCHroot}$. This is shown in Fig. 3.

Fig. 3 illustrates a channelization code tree for use under
15 one scrambling code. The black nodes in the tree are reserved
for PDSCHs under different beams. The root PDSCH code marked
by a double-lined arrow is reserved so fast bit rate
allocation/change can be accommodated for the different
beams. Codes in the sub-tree below the root PDSCH code and
20 circumscribed by a hatched circle can be used by PDSCHs in
parallel beams. DCH's marked by simple arrows to the right of
the hatched circle can use the rest of the tree.

Alternatively, one logical DSCH (Downlink Shared Channel) may
25 be assigned per beam, so a separate root PDSCH channelization
code can be reserved for each beam. However, this option will
result in loss of code trunking efficiency, because it is
highly unlikely that all PDSCHs under different beams will be
operating at high bit rates simultaneously. Application of
30 smart packet scheduling for parallel beams, performed by
packet scheduler 5 of Fig. 2, can be designed to avoid such
loss of code trunking efficiency. This will be discussed
further below.

35 Using link adaptation (LA) techniques e.g. for one scrambling

code of Fig 3 or for a logical DSCH, the selected bit rate
for each UE (user equipment) on the DSCH can be expressed as
a function of the power allowed for the PDSCH and the
experienced SIR (signal-to-interference-ratio) at the UE.

5   This basically implies that UEs close to the BS typically get
assigned a higher bit rate, as these UEs have a higher SIR.
However, a UE is not always assigned the bit rate according
to the LA criteria based on reserved transmit power and SIR
at the UE. There are other limitations such as the SF

10 (Spreading Factor) of the root channelization code which set
an upper limit on the maximum bit rate.

In the following, aspects of the invention related to code
reservation strategies will be described.

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For cases where the PDSCHs under the same scrambling code,
but different beams, share the same PDSCH root channelization
code, a minimum assumed SF for beam number m ($SF_{min}[m]$) will
be introduced. This means that the SF of the root PDSCH code

20 should be selected according to the set of minimum SFs
assumed for the different beams, i.e.

$$SF_{DSCHroot} = f\left(\{SF_{min}[m]\}_{m \in SC}\right),$$ (1)

where $\{SF_{min}[m]\}_{m \in SC}$ is the set of assumed minimum SFs for the

25 beams transmitted under the same scrambling code, where the
set SC contains the beam numbers which are transmitted under
the same scrambling code. A conservative approach is to
select the function $f()$ so simultaneous transmission in all
the beams under the same scrambling code is possible with the

30 minimum assumed SF. However, the probability of that happing
is likely to be small, which lead to the conclusion that the
latter approach would result in waste of code resources.

Assuming that one scrambling code will most probably cover C=3-5 beams, at least some of the embodiments of the present invention use the following simplified approach, where

$$SF_{DSCHroot} = f\left(\left\{SF_{\min}[m]\right\}_{m \in SC}\right)$$
$$= Min\left\{\left\{SF_{\min}[m]\right\}_{m \in SC}\right\}/Q \qquad (2)$$

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with $Q=2^n$ and $C \geq Q$, where n is a positive integer, i.e. $n \in [0,1,2,3....]$.

Assuming that the root PDSCH code is shared between e.g. C=4
10   beams, then Q=4 will result in a case where the reserved code resources allow for simultaneous transmission in all four beams with the minimum SF. Thus, code load becomes identical to the case where separate root PDSCH codes are reserved for each beam.

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However, by setting Q=2 (assuming C=4 four beams) one obtains a gain in terms of less reserved code resources. Actually, preferably 50% less code resources are reserved compared to the case where separate root PDSCH codes are reserved per
20   beam. As an example, selecting Q=2 (still assuming four beams), the embodiments of the invention can ensure that the beam with the minimum assumed SF can transmit at the maximum allowed bit rate, while the other PDSCHs under different beams (but same scrambling code) can be active at lower bit
25   rates.

This choice also makes it possible that two PDSCHs are operated simultaneously at $Min\left\{\left\{SF_{min}[m]\right\}_{m \in sc}\right\}$, assuming that the remaining PDSCHs are silent.

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Using smart packet scheduling for parallel beams, it can be avoided that all beams transmit on the PDSCH with high bit

rates (low SF) simultaneously. This is illustrated in the
following.

In the following, aspects of the invention related to smart

5 parallel packet scheduling will be described.

In order to illustrate the basic principles of smart parallel
packet scheduling, an example will be considered where PDSCHs
are transmitted under four beams, which all share the same

10 root PDSCH channelization code. Under each of these beams,
there are UEs (User Equipments) which can operate at high,
medium, and low bit rates.

An example of an appropriate scheduling strategy, applied by

15 packet scheduler 5 shown in Fig. 2, is illustrated in Figure
4. Here it is seen that the scheduling in the individual
beams #1 to #4 is coordinated, so only one of the beams #1 to
#4 is transmitting with a high bit rate during the same time
period. The different time periods (say scheduling slots) are

20 balanced so they require nearly the same amount of code
resources.

A comparative example of poor scheduling is shown in Fig. 5.
Here high bit rates are transmitted to two UEs

25 simultaneously. This sets high requirements to the amount of
reserved code resources, and should therefore be avoided
whenever possible.

The proposed scheduling strategy can also be combined with

30 quality-of-service (QoS) differentiation schemes, so packets
are prioritized according to QoS attributes.

HSDPA is basically an extension of the DSCH. The presented
invention is therefore also applicable for the HSDPA.

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The invention provides a code efficient solution for cases where multiple beamforming PDSCHs are applied. The method basically provides a code trunking efficient solution. This means that code resources are better utilized, so the BS can

5   carry a higher amount of traffic (e.g. higher number of user) with less scrambling codes. This is a major advantage, as introduction of additional scrambling codes typically results in a capacity loss, as the orthogonality properties are partly destroyed within the cell. The present invention will

10   therefore result in a capacity gain.

This gain is also present for HSDPA, even though HSDPA has the option of using higher order modulation schemes to avoid code blocking. This is true since usage of multiple codes

15   (equivalent to lower SF) is more spectral efficient, compared to using higher order modulation techniques.

As mentioned earlier, the present invention can be implemented e.g. within the limits of the UMTS specifications

20   (i.e. the 3GPP specifications). The best mode of the invention depends on the selected antenna array configuration, number of beams, scrambling code configuration, etc. For a typical scenario with a four element uniform linear antenna array and six beams, where two

25   scrambling codes are used to cover three beams each (C=3), it is proposed to select Q=2.

The proposed invention can e.g. be implemented in the RNC (radio network controller) and/or the BS, and can e.g. be

30   part of a RAN (Radio Access Network), e.g. an UTRAN (Universal Terrestrial RAN) solution as well as IP-RAN.

The presented algorithm opens for effective utilization of the DSCH when using link adaptation techniques as well as

35   HSDPA.

The invention furthermore improves throughput of packet mode data, e.g. in SA BTS (IP RAN).

5   While the invention has been described with reference to preferred embodiments, the description is illustrative of the invention and is not to be construed as limiting the invention. The invention may also be implemented in other ways, e.g. by combining, in any arbitrary fashion, one or

10   more features of one or some embodiments with one or more features of other embodiments. Various modifications and applications may occur to those skilled in the art without departing from the scope of the invention as e.g. defined by the appended claims.